APPENDIX D

LONG-TERM PERFORMANCE EVALUATION

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APPENDIX D. LONG-TERM PERFORMANCE EVALUTAION

This Appendix describes the methodology used by the U.S. Department of Energy (DOE) in determining long-term impacts that could occur from implementation of the action alternatives described in Chapter 2 of this Supplemental Environmental Impact Statement (SEIS).

In order to estimate the impacts of no action in the long term, DOE must assume that the HLW remains in the HLW storage tanks and no action is ever taken to ensure safe management. In this worst-case scenario, the HLW tanks would eventually fail and the contents would be released to the groundwater and eventually, to surface water. DOE has not attempted to model this scenario. Some indication of the potential for impacts may be gained, however, from a comparison with modeling results DOE prepared for the *High-Level Waste Tank Closure Draft Environmental Impact Statement* (DOE 2000).

Under the No Action alternative in the Tank Closure Draft EIS (DOE 2000), DOE would remove most of the waste from the tanks and spray water wash the tanks, but would take no further action to stabilize the waste remaining in the tanks or to stabilize the tank systems themselves. Under the tank closure scenario, the tanks would eventually fail (after a period of perhaps several hundred years), creating physical hazards to humans and wildlife in the area and releasing the residual HLW to the groundwater at SRS. DOE estimated that residual waste in the F- and H-Area Tank Farms would contain about 200 curies of long half-life isotopes, technetium-99 and plutonium-239, and 9,900 curies of cesium-137, which has a relatively short half-life. DOE modeled the eventual release of these contaminants to the groundwater at SRS. The modeling showed that an adult resident in the F-Area Tank Farm could receive a lifetime radiation dose of 430 millirem (primarily from groundwater), and incur a risk of 2.2×10^{-4} of incurring a fatal cancer. The greatest risk occurs within about 500 years of tank abandonment, but doses for residents would be greater than 10 millirem for over 1,000 years.

In contrast, if DOE were to take no action and leave the HLW in the tanks at SRS, approximately 450,000,000 curies (160,000,000 in salt component, and 290,000,000 in the sludge component, assuming that about 10 percent of the curies in the sludge component have been vitrified in DWPF) would be available for release to the groundwater. While modeling would be required to calculate exposures and health effects over time, it is clear that the impacts to human health resulting from a No Action alternative would be catastrophic.

The discussion in this Appendix is centered around the action alternatives. The long-term analysis covers that period of time following 100 years of institutional control as specified in DOE Order 435.1 for determining impacts of low-level waste disposal facilities. DOE expects the primary source of long-term impacts to be saltstone disposal in Z Area. In accordance with the requirements of DOE Order 5480.2A, the *Radiological Performance Assessment for the Z-Area Saltstone Facility* (WSRC 1992), referred to as the RPA, was prepared based on the expected chemical composition of the salt solution that would be transferred from the In-Tank Precipitation (ITP) Facility and the Effluent Treatment Facility. As part of this SEIS process, DOE reviewed the RPA to determine how its conclusions could change if the chemical composition of the salt solution changed as a result of the alternatives analyzed in this SEIS, and how information from the RPA could be used to estimate impacts of the alternative salt solutions.

Although new groundwater models for the Savannah River Site (SRS) are currently under development, DOE believes that the methodology used in the RPA provides a reasonable basis for estimating impacts in this SEIS. Therefore, DOE has chosen to use the general methodology of the RPA to the maximum extent practical, making changes only for those parameters that are unique to the proposed new processes and those that were not analyzed in the RPA, such as differing concentrations of salt in the feed solution among alternatives.

D.1 Description of RPA Approach

This section provides a brief overview of the general methodology used to determine impacts in the RPA. The reader is referred to the RPA (WSRC 1992) for additional details.

As stated, the RPA based its analysis on the source term in the salt solution that was expected to be transferred to the Saltstone Manufacturing and Disposal Facility from the ITP and the Effluent Treatment Facilities, with the bulk of the material coming from ITP.

Because the high-level waste (HLW) tanks contain a myriad of fission products, activation products, actinides, and chemicals, the RPA performed a sensitivity analysis to identify those contaminants that would be most likely to present long-term impacts. This was based on a variety of factors, such as the quantity of the material projected to be present in the saltstone, the half-lives of the radiological constituents, and the ability of the saltstone to chemically bind the contaminants to minimize leaching.

The RPA also considered the pathways by which individuals could be exposed in the future to determine which pathways warranted detailed analysis. Based on early estimates, the primary pathways to which a person could be exposed were the following:

- A drinking water scenario where the individual consumes water from a well drilled into the aquifer that contains contaminants from the saltstone. This scenario is not assumed to be possible until at least 100 years post-closure.

- An agricultural scenario, in which an individual unknowingly farms on the soil above the saltstone vaults and constructs a home on the vaults. In this scenario, the individual is assumed to derive half of his vegetable consumption from a garden planted in contaminated soil located over the vaults. The time spent gardening is assumed to be short (100 hr/yr), compared to the amount of time spent indoors (4000 hr/yr) or farming. Doses from external radiation, inhalation, incidental soil ingestion, and vegetable ingestion are calculated only for indoor residence and outdoor gardening activities. Since the farming activities are assumed to occur over a widespread area that would include uncontaminated and undisturbed soil not subject to irrigation with contaminated water, the meat and milk pathways would not contribute significantly to the individual's dose. DOE expects that the saltstone would remain relatively intact for an extended period of time; therefore, DOE does not believe this scenario would be reasonable until approximately 10,000 years post-closure because, at least until that time, an individual could identify that he was digging into a cementitious material. However, for conservatism, DOE calculated the impacts of the agricultural scenario at 1,000 years post-closure.

- A residential scenario, in which an individual constructs and lives in a permanent residence on the vaults. This scenario has two options: construction at 100 years post-closure and construction at 1,000 years post-closure (evaluated as part of the agricultural scenario). Under the first option, a sufficient layer of soil would be present over the still-intact vaults so that the resident would be unaware that the residence was constructed on the vaults. Under the second option, the saltstone is assumed to have weathered sufficiently so that the resident could construct a residence without being aware of the presence of the saltstone.

The RPA assumed that institutional control would be maintained for 100 years after closure, during which time the land encompassing the saltstone vaults would be managed to prevent erosion or other conditions that would lead to early degradation of the vaults. The public is also assumed to have no access to Z Area during this time.

The analysis of groundwater impacts is based on PORFLOW-3D, a 3-dimensional finite difference model of flow and transport for both the near field and the far field. The near-field analysis considers flow and transport from the

ground surface, through the saltstone, vault, and unsaturated zone, to the water table. The far-field analysis considers flow and transport through the water table and underlying aquifers. The ultimate results of the modeling effort are the maximum concentrations of the contaminants of interest at a point 100 meters downgradient from the downgradient edge of the disposal facility. It is at this "compliance" point that the groundwater quality is compared to water quality standards.

The analysis of doses from other pathways in the agricultural and residential scenarios begins with the calculated concentrations in the saltstone and surrounding soil, to which the appropriate pathway transfer coefficients and dose conversion factors are applied.

The RPA examined the potential impacts of saltstone disposal for the cases in which the saltstone remained intact and in which the saltstone failed structurally. For groundwater modeling, the greater impacts presented in the RPA are associated with failed saltstone. Therefore, this SEIS presents the results associated with failed saltstone.

D.2   Modifications to the RPA Approach for the SEIS Analysis

Because of the extensive nature of the RPA, DOE chose to rely on many of the technical bases presented in it. However, DOE did modify the calculations in the RPA to account for the following:

- the differences in salt solution concentrations for the Ion Exchange alternative, the Solvent Exchange alternative, and the Direct Disposal in Grout alternative from those for the ITP case (equivalent to the Small Tank Precipitation alternative)

- the difference in number and design of vaults for the current suite of alternatives, compared to the vaults analyzed in the RPA

- the need to calculate groundwater concentrations 1 meter downgradient from the downgradient edge of the disposal facility to be consistent with the SRS Tank Closure EIS. Because Z Area is a low-level waste disposal facility, it is exempt from the Resource Conservation and Recovery Act (RCRA) regulations pertinent to the high-level waste tanks that require an assessment of impacts 1 meter downgradient. The analysis is included to better compare the impacts of the two actions.

- the need to calculate groundwater concentration at the seeplines of nearby streams to determine impacts on ecological resources

- the difference in measured properties of the current formulation of saltstone, compared to those analyzed previously in the RPA.

The saltstone concentrations for analysis in this SEIS were based on the concentrations in the original RPA, adjusted to account for the increase in sodium molarity as projected in the engineering flow sheets (WSRC 1998) for the alternatives. Increased sodium molarity is indicative of increased overall concentrations; the alternatives with higher sodium molarities were assumed to also have higher overall concentrations of other constituents in proportion to the increase in sodium molarity. The concentration of cesium isotopes for the Direct Disposal in Grout alternative was calculated, based on the estimated cesium-137 inventory in the HLW tanks and the volume of saltstone produced. The concentrations of other cesium isotopes were calculated, based on isotopic ratios derived from the RPA. For this SEIS, the source information from Tables A-1 and A-2 in Appendix A was used.

The methodology used in the RPA for the agricultural and residential scenarios was unchanged and is not repeated in this Appendix. Most of the other changes to calculations in the RPA pertained to groundwater modeling, as discussed in the following section.

D.3 Groundwater Modeling Modifications

The present analysis is based on the results of the detailed peer-reviewed model in the RPA. The results presented there are used here, for conditions at which the RPA calculations and the SEIS are equivalent. For non-equivalent conditions, the RPA results are scaled by use of an analytical model which includes all of the important transport mechanisms. Modifications to the previous study were included to account for changes in the release rate to the water table (Table D-1). These changes would occur because of changes in radionuclide content of the saltstone among the alternatives, because of modifications to saltstone transport parameters established in Langton 1999, and because of a change in the total number of vault cells from the earlier study. Extensions to the previous modeling study were also included to allow for calculation of concentrations at locations other than the compliance point. Specifically, concentrations were calculated for a well 1-meter downgradient of Z Area and for the seeplines of the water table (to McQueen Branch) and Gordon (to Upper Three Runs) aquifers. The seepline aquifer discharge points were taken to be 450 and 1,500 meters, respectively, from the downgradient edge of the facility.

The extension of the previous modeling study was based on the assumption that an analytical model of aquifer transport, which includes the important mechanisms included in the original study, would simulate the relative downgradient concentrations in the aquifer. The model chosen (Pigford et al. 1980) considers three-dimensional dispersion, advection, adsorption, and decay from a continuous release. Continuous release is necessary because of the long-term releases from the facility. This model includes daughter ingrowth and independent transport (i.e., with the daughter's transport parameters), although the contaminants of concern for the present study are not daughter products. The model, as originally presented, calculates concentration as a function of release rate, aquifer velocity, dis-

persivity (in three dimensions), decay rate, adsorption coefficient, and time. The concentrations are given in terms of distance (longitudinal, lateral, and vertical to aquifer flow) from a point source release. Because of the size of the facility (on the order of a few hundred meters on a side), relative to the downgradient distances of interest (i.e., 1 and 100 meters), it was necessary to modify the point source solution to account for an area source. The point source solution of the original source was generalized to a horizontal area source solution (consistent with the saltstone footprint) by integrating the point source solution over the facility area and dividing by this area. If the area source solution described above is denoted $C_a(x,y,z,t)$ and the solution of the previous detailed model is $C_{rpa}(100,0,0,t_{max})$ (i.e., the maximum concentration at the compliance point), then the concentration as presented here is estimated as:

$$Cs = \frac{C_{rpa}(100,0,0,t_{max}) \times C_a(x,y,z,t)}{C_a(100,0,0,t_{max})}$$

where C = concentration, x = distance along aquifer flow path, y = distance horizontally transverse to aquifer flow, z = vertical distance (all directions measured from the projection of the middle of the downgradient edge of the facility on the water table), and t = time from initial release to water table.

For the conditions analyzed in the RPA (x = 100m, y = z = 0, t = t_{max}), Cs = C_{rpa}), comparing Table D-2 with the results of the RPA illustrates some of the changes from the RPA analysis to this SEIS. The Small Tank Precipitation alternative is most similar to the process analyzed in the RPA; the Direct Disposal in Grout alternative is the least similar. Therefore, the Small Tank Precipitation alternative results would be expected to be most similar to the RPA results, based on the number of vault cells (see Table D-1); with fewer vault cells, the other cesium removal alternatives should result in smaller concentrations at 100 meters. This is the case (Table D-2). Using this reasoning, the Direct Disposal in Grout alternative would also be expected to result in smaller concentrations than

Table D-1. Modifications to the RPA's parameters for this SEIS.

Parameter	Previous study (RPA)	Small Tank Precipitation	Ion Exchange	Solvent Extraction	Direct Disposal in Grout
Number of cells	174	109	90	101	82
Waste solution sodium molarity	4.6	4.6	5.3	4.3	5.6
Nitrate diffusivity through saltstone, (square centimeters per second)	5.07×10^{-9}	6.00×10^{-8}	6.00×10^{-8}	6.00×10^{-8}	6.00×10^{-8}
Cesium adsorption co-efficient in saltstone (milliliters per gram)	2	200	200	200	200

the Small Tank Precipitation alternative because it has fewer vault cells. However, in this case, a reduction in the number of vault cells is offset by an increase in solution sodium molarity of Direct Disposal in Grout saltstone (Table D-2). Both alternatives result in slightly lower concentrations than that of the RPA analysis. Note that the RPA did not analyze the concentration of Cs-135; it is a relatively important contributor only to the Direct Disposal in Grout alternative.

The number of saltstone vaults is presented in Chapter 2 and Appendix A of this document. The effect of reducing the number of saltstone vaults on the modeling is to decrease the surface area through which precipitation will infiltrate and leach the constituents; the previous study's release rates were therefore multiplied by the ratio of facility surface areas. The saltstone concentration increases with increasing sodium molarity; the previous study's release rates were multiplied by the ratio of molarities. The exception to the latter was for the cesium isotopes in the Direct Disposal in Grout alternative, as described in Chapter 2 and Appendix A of this SEIS.

A recent laboratory study (Langton 1999) indicates that the diffusivity of nitrate through saltstone is greater than that assumed in the previous RPA. This has the potential to increase the nitrate release rate from the saltstone after failure. The RPA showed that the nitrate release has two components: an advective "fracture" release (decreasing over time) from the cracks formed in the grout; and a later "intact" diffusive

release from the internal pores of the grout to the fracture planes. Changes in the "intact" diffusive release have been shown to be proportional to the square root of the ratio of diffusivities (Wallace 1986). The time-dependent nitrate release rate indicated in the previous RPA was re-examined in light of the revision in diffusivity indicated in Table D-1. It was found that the initial "fracture" release was larger than the sum of the later "fracture" releases plus the "intact" release. The initial "fracture" release rate, which is independent of diffusivity, was conservatively assumed for this analysis.

The Langton study also indicated an increase in cesium adsorption coefficient in saltstone from that used in the RPA. This increase in saltstone constituent adsorption coefficient results in an approximately linear decrease in cesium concentration in pore water and, therefore, an approximately linear decrease in the cesium release rate.

The values from the Langton study are expected to better represent the conditions for salt processing than the values chosen for the RPA. The former were laboratory measurements of adsorption between the constituents studies (nitrate and cesium) and the saltstone formulae that would be used for this project; the latter were conservatively low choices from a range of literature values describing adsorption of the constituents with concrete not specific to salt processing. Use of the cesium adsorption coefficient suggested by the Langton study, in place of the

Table D-2. Maximum Groundwater concentrations at 1 meter downgradient, 100 meters downgradient, and at the seepline.[a]

		Carbon-14 (picocuries per liter)[b]	Selenium-79 (picocuries per liter)[b]	Technetium-99 (picocuries per liter)[b]	Tin-126 (picocuries per liter)[b]	Iodine-129 (picocuries per liter)[b]	Cesium-135 (picocuries per liter)[b]	Nitrate (milligrams per liter)[c]
1-meter concentrations								
Upper Three Runs Aquifer	Small Tank Precipitation	1.0×10^{-4}	7.0	17	0.0039	0.11	4.0×10^{-5}	56
	Ion Exchange	1.1×10^{-4}	8.2	20	0.0047	0.13	4.5×10^{-5}	66
	Solvent Extraction	9.4×10^{-5}	6.4	15	0.0036	0.10	3.7×10^{-5}	51
	Direct Disposal in Grout	1.2×10^{-4}	8.2	20	0.0046	0.13	0.50	66
Gordon Aquifer	Small Tank Precipitation	6.7×10^{-4}	42	104	0.024	0.68	2.5×10^{-4}	338
	Ion Exchange	6.7×10^{-4}	49	121	0.029	0.82	2.7×10^{-4}	395
	Solvent Extraction	5.6×10^{-4}	38	94	0.022	0.63	2.3×10^{-4}	307
	Direct Disposal in Grout	7.2×10^{-4}	49	120	0.029	0.81	3.1	394
100-meter concentrations								
Upper Three Runs Aquifer	Small Tank Precipitation	8.2×10^{-6}	0.59	1.4	3.0×10^{-4}	0.0096	3.5×10^{-6}	4.8
	Ion Exchange	8.9×10^{-6}	0.63	1.5	3.2×10^{-4}	0.01	3.7×10^{-6}	5.1
	Solvent Extraction	7.5×10^{-6}	0.54	1.3	2.7×10^{-4}	0.0088	3.2×10^{-6}	4.4
	Direct Disposal in Grout	9.6×10^{-6}	0.68	1.7	3.5×10^{-4}	0.011	4.2×10^{-2}	5.6
Gordon Aquifer	Small Tank Precipitation	5.0×10^{-5}	3.5	8.8	0.0019	0.059	2.2×10^{-5}	29
	Ion Exchange	5.3×10^{-5}	3.8	9.4	0.002	0.063	2.3×10^{-5}	31
	Solvent Extraction	4.5×10^{-5}	3.2	8.0	0.0017	0.054	2.0×10^{-5}	26
	Direct Disposal in Grout	5.8×10^{-5}	4.1	10	0.0022	0.069	0.26	33
	RPA[c]	6.0×10^{-6}	4.4	11	0.0022	0.075	Not calculated	36
Seepline concentrations								
McQueen Branch	Small Tank Precipitation	1.9×10^{-6}	0.16	0.42	5.7×10^{-5}	0.0028	9.8×10^{-7}	1.4
	Ion Exchange	2.1×10^{-6}	0.17	0.44	6.1×10^{-5}	0.0029	1.0×10^{-6}	1.5
	Solvent Extraction	1.8×10^{-6}	0.15	0.38	5.2×10^{-5}	0.0029	8.9×10^{-7}	1.3
	Direct Disposal in Grout	2.2×10^{-6}	0.19	0.48	6.6×10^{-5}	0.0032	0.012	1.6
Upper Three Runs	Small Tank Precipitation	2.0×10^{-6}	0.23	0.66	3.9×10^{-5}	0.0045	1.5×10^{-6}	2.2
	Ion Exchange	1.9×10^{-6}	0.23	0.64	3.9×10^{-5}	0.0044	1.5×10^{-6}	2.1
	Solvent Extraction	1.7×10^{-6}	0.20	0.58	3.5×10^{-5}	0.0039	1.3×10^{-6}	1.9
	Direct Disposal in Grout	2.1×10^{-6}	0.25	0.72	4.3×10^{-5}	0.0049	0.017	2.4

Source: WSRC (1992) Table 4.1-6.

a. The concentrations reported are the maximum for each nuclide and alternative that would occur in the 1,000-year period of analysis. The maximum occurrences are not simultaneous; they would occur at different times during the 1,000-year time period.

b. Concentrations of radiological constituents are presented in units of picocuries per liter.

c. Concentrations of nonradiological constituents are presented in units of milligrams per liter.

literature value used in the RPA, will significantly decrease the predicted cesium transport.

All other parameters used in the previous study were used in the present study. Because the previous study only considered a single point (compliance point), a single value of dispersivity for each direction was used. The values used at that location (3 meters for longitudinal, 0.3 meters for transverse) were generalized to other distances by assuming that the ratio of distance to dispersivity is constant. The vertical dispersivity was taken as 2.5×10^{-3} times the longitudinal dispersivity (Buck et al. 1995).

D.4   Results

Table D-2 presents the maximum groundwater concentrations calculated by using the methodology described above. For comparison purposes, the results from the RPA are presented at the 100m compliance point. Table D-3 presents the radiological doses resulting from concentrations of radiological constituents in the groundwater. The source information in these tables was used for the SEIS.

Table D-4 presents the calculated doses for the agricultural and residential scenarios. For all the scenarios, most of the dose is due to external exposure. A range of external radiation exposures was calculated, based on the same assumptions regarding post-closure conditioning in the vaults used in the RPA. These assumptions included the application of two mutually exclusive approaches for deriving dose correction factors. One approach considered a finite size of the excavation, which would not uncover the area of an entire vault and would result in a four-fold reduction in external dose relative to the dose from a fully uncovered vault. The other approach assumed that a minimum soil thickness of 30 cm (12 inches) would be required to sustain plant growth, and would therefore provide some additional shielding. The application of either of these factors to the maximum unshielded dose results in a range of doses differing by a factor of approximately seven, with the first approach resulting in the higher dose. The differences in the ranges of external doses

among alternatives are due to the different concentrations of radionuclides. For the 100-year residential exposure scenario, the external dose is due primarily to cesium-137; for all other alternatives and scenarios, the external dose is due primarily to tin-126 and its decay products.

D.5   Discussion of Uncertainty

In this SEIS, DOE has made assumptions regarding the numerical parameters that affect the calculated impacts. Some uncertainty is associated with the values of these parameters, due to unavailable data and current knowledge concerning closure processes and long-term behaviors of materials. The principal parameters that affect modeling results are the following:

- **Saltstone characteristics:** The volume of saltstone and constituent chemical and radionuclide concentrations determine the concentrations of release constituents at any given location. As discussed earlier, the concentrations of the saltstone constituents inventory are based primarily on data previously presented in the RPA and updated with information from more recent engineering flow sheets.

- **Hydraulic conductivity:** The rate of water movement through material is ultimately affected by the hydraulic conductivity of the geologic strata underneath the source. Generally, the grout or concrete basemat is the limiting layer with regard to water infiltration. Over time, cracks developing in the saltstone increase the hydraulic conductivity dramatically, making more water available to carry contaminants to the aquifer. This increase results in greater doses/concentrations, due to the increased transport of the contaminants.

- **Distribution coefficient:** The distribution coefficient (K_d) affects the rate at which contaminants move through the geologic strata. Large K_d values provide holdup time for short-lived radionuclides.

Table D-3. Radiological doses due to consumption of groundwater 1 meter downgradient, 100 meters downgradient, and at the seepline.

Downgradient		Total (millirem per year)	Carbon-14 (millirem per year)	Selenium-79 (millirem per year)	Technetium-99 (millirem per year)	Tin-126 (millirem per year)	Iodine-129 (millirem per year)	Cesium-135 (millirem per year)
1-meter doses								
Upper Three Runs Aquifer	Small Tank Precipitation	0.080	1.5×10^{-7}	4.3×10^{-2}	1.6×10^{-2}	5.0×10^{-5}	2.2×10^{-2}	2.1×10^{-7}
	Ion Exchange	0.095	1.7×10^{-7}	5.0×10^{-2}	1.9×10^{-2}	6.1×10^{-5}	2.6×10^{-2}	2.3×10^{-7}
	Solvent Extraction	0.074	1.4×10^{-7}	3.9×10^{-2}	1.5×10^{-2}	4.7×10^{-5}	2.0×10^{-2}	1.9×10^{-7}
	Direct Disposal in Grout	0.096	1.8×10^{-7}	5.0×10^{-2}	1.9×10^{-2}	6.0×10^{-5}	2.6×10^{-2}	2.6×10^{-3}
Gordon Aquifer	Small Tank Precipitation	0.49	9.1×10^{-7}	2.6×10^{-1}	9.8×10^{-2}	3.1×10^{-4}	1.4×10^{-1}	1.3×10^{-6}
	Ion Exchange	0.58	1.0×10^{-6}	3.0×10^{-1}	1.2×10^{-1}	3.8×10^{-4}	1.6×10^{-1}	1.4×10^{-6}
	Solvent Extraction	0.45	8.4×10^{-7}	2.3×10^{-1}	8.9×10^{-2}	2.9×10^{-4}	1.3×10^{-1}	1.2×10^{-6}
	Direct Disposal in Grout	0.57	1.1×10^{-6}	3.0×10^{-1}	1.1×10^{-1}	3.8×10^{-4}	1.6×10^{-1}	1.6×10^{-2}
100-meter doses								
Upper Three Runs Aquifer	Small Tank Precipitation	6.8×10^{-3}	1.2×10^{-8}	3.6×10^{-3}	1.4×10^{-3}	3.8×10^{-6}	1.9×10^{-3}	1.8×10^{-8}
	Ion Exchange	7.3×10^{-3}	1.3×10^{-8}	3.8×10^{-3}	1.5×10^{-3}	4.2×10^{-6}	2.1×10^{-3}	2.0×10^{-8}
	Solvent Extraction	6.2×10^{-3}	1.1×10^{-8}	3.3×10^{-3}	1.2×10^{-3}	3.5×10^{-6}	1.8×10^{-3}	1.7×10^{-8}
	Direct Disposal in Grout	7.9×10^{-3}	1.4×10^{-8}	4.2×10^{-3}	1.6×10^{-3}	4.5×10^{-6}	2.2×10^{-3}	2.2×10^{-4}
Gordon Aquifer	Small Tank Precipitation	4.2×10^{-2}	7.4×10^{-8}	2.2×10^{-2}	8.4×10^{-3}	2.5×10^{-5}	1.2×10^{-2}	1.1×10^{-7}
	Ion Exchange	4.4×10^{-2}	8.0×10^{-9}	2.3×10^{-2}	8.9×10^{-3}	2.7×10^{-5}	1.3×10^{-2}	1.2×10^{-7}
	Solvent Extraction	3.8×10^{-2}	6.8×10^{-8}	2.0×10^{-2}	7.6×10^{-3}	2.2×10^{-5}	1.1×10^{-2}	1.1×10^{-7}
	Direct Disposal in Grout	4.8×10^{-2}	8.7×10^{-8}	2.5×10^{-2}	9.7×10^{-3}	2.9×10^{-5}	1.4×10^{-2}	1.3×10^{-3}
Seepline doses								
McQueen Branch	Small Tank Precipitation	1.9×10^{-3}	2.9×10^{-9}	1.0×10^{-3}	4.0×10^{-4}	7.4×10^{-7}	5.6×10^{-4}	5.1×10^{-9}
	Ion Exchange	2.0×10^{-3}	3.1×10^{-9}	1.0×10^{-3}	4.2×10^{-4}	7.9×10^{-7}	5.9×10^{-4}	5.4×10^{-9}
	Solvent Extraction	1.7×10^{-3}	2.7×10^{-9}	9.0×10^{-4}	3.6×10^{-4}	6.7×10^{-7}	5.0×10^{-4}	4.8×10^{-9}
	Direct Disposal in Grout	2.2×10^{-3}	3.4×10^{-9}	1.1×10^{-3}	4.5×10^{-4}	8.5×10^{-7}	6.4×10^{-4}	6.0×10^{-5}
Upper Three Runs	Small Tank Precipitation	2.9×10^{-3}	2.9×10^{-9}	1.4×10^{-3}	6.3×10^{-4}	5.1×10^{-7}	8.9×10^{-4}	7.8×10^{-9}
	Ion Exchange	1.8×10^{-3}	2.9×10^{-9}	1.4×10^{-3}	6.1×10^{-4}	5.0×10^{-7}	8.7×10^{-4}	7.7×10^{-9}
	Solvent Extraction	2.5×10^{-3}	2.6×10^{-9}	1.2×10^{-3}	5.5×10^{-4}	4.5×10^{-7}	7.8×10^{-4}	7.3×10^{-9}
	Direct Disposal in Grout	3.2×10^{-3}	3.2×10^{-9}	1.5×10^{-3}	6.8×10^{-4}	5.6×10^{-7}	9.7×10^{-4}	8.5×10^{-5}

Table D-4. Radiological doses from the agricultural and residential scenarios.

	Small Tank Precipitation	Ion Exchange	Solvent Extraction	Direct Disposal in Grout
Agricultural scenario at 1,000 years post-closure[a]				
Inhalation while outdoors (millirem per year)	0.010	0.012	0.0096	0.013
Ingestion of vegetables (millirem per year)	42	49	39	52
Incidental ingestion of soil (millirem per year)	0.7	0.81	0.66	0.88
Inhalation while indoors (millirem per year)	0.26	0.3	0.24	0.32
External radiation while outdoors[b] (millirem per year)	0.045-0.33	0.052-0.39	0.042-0.31	0.055-0.41
External radiation while indoors[b] (millirem per year)	9.2-69	11-80	8.6-65	11-85
Total (millirem per year)	52-110	61-130	49-110	64-140
Residential scenario at 100 years post-closure[b] (millirem per year)	0.015-0.11	0.017-0.13	0.014-0.10	150-1200
Residential scenario at 1,000 years post-closure[a,b] (millirem per year)	9.2-69	11-80	8.6-65	11-85

a. Residential scenario at 1,000 years post-closure is also included in the agricultural scenario.
b. The range of values for external radiation is due to different assumptions regarding size of the source and the amount of shielding provided by topsoil.

- **Vadose zone thickness:** The thickness of the geologic strata between the contaminated region and the aquifer does not necessarily reduce the concentration as much as it slows movement of contaminants toward the aquifer. For shorter-lived radionuclides, extra time provided by thicker strata decreases the activity of the contaminants reaching the aquifer.

- **Distance downgradient to receptor location:** The distance to a given receptor location affects (a) the time at which contaminants will arrive at the receptor location, and (b) the extent of dispersion that occurs. For greater distances, longer travel times will occur, resulting in lower activity values for short-lived radioactive constituents and greater dispersion for all constituents.

DOE recognizes that, over the period of analysis in this SEIS, there is also uncertainty in the structural behaviors of materials and the geologic and hydrogeologic setting of the SRS. DOE realizes that overly conservative assumptions can be used to bound the estimates of impacts; however, this approach could result in masking differences of impacts among alternatives. Therefore, DOE has used assumptions in its modeling analysis that are reasonable, based on current knowledge, to develop meaningful comparisons among alternatives considered.

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